

MULTIPLE ACCESS VEIN FILTER

BACKGROUND

Technical Field

This application relates to a vascular filter and more particularly to a vein filter for capturing blood clots within the vessel.

Background of Related Art

Passage of blood clots to the lungs is known as pulmonary embolism. These clots typically originate in the veins of the lower limbs and can migrate through the vascular system to the lungs where they can obstruct blood flow and therefore interfere with oxygenation of the blood. Pulmonary embolisms can also cause shock and even death.

In some instances, blood thinning medication, e.g. anticoagulants such as Heparin, or sodium warfarin can be given to the patient. These medications, however, have limited use since they may not be able to be administered to patients after surgery or stroke or given to patients with high risk of internal bleeding. Also, this medication approach is not always effective in preventing recurring blood clots.

Therefore, surgical methods to reduce the likelihood of such pulmonary embolisms by actually blocking the blood clot from reaching the lungs have been developed. One surgical method of treatment involved major surgery where the size of the vessel lumen was restricted by placement of ligatures or clips around the vein, e.g. the inferior vena cava which transports blood from the lower portion of the body to the heart and lungs. This prevented passage of dangerously large blood clots through the vein to the lungs. However, this approach is an invasive surgical procedure, requiring an abdominal incision and general anesthesia and frequently causing vessel thrombosis and lower extremity swelling. Also, there is a lengthy patient recovery time and additional hospital and surgeon expenses associated with this major surgery. In fact, oftentimes, the patients requiring the surgery are unhealthy and the major surgery and general anesthesia poses a risk in and of itself.

To avoid such invasive surgery, less invasive surgical techniques have been developed. These involve the placement of a mechanical barrier in the inferior vena

portion in an expanded configuration is less than a transverse dimension of the anchoring portion in an expanded configuration, and a transverse dimension of the second filtering portion is less than a transverse dimension of the second anchoring portion. The first and second filtering portions are positioned closer to each other than the first and second anchoring portions, and the anchoring portions are formed on first and second opposite portions of the vessel filter. Preferably a sleeve is positioned between the first and second filter portions.

Preferably the filtering portions and the anchoring portions are formed by three wires and a first anchoring member extends from the first anchoring portion and a second anchoring member extends from the second anchoring portion, each anchoring member having first and second opposing sharpened ends for engaging the vessel wall. In a collapsed configuration of the vessel filter the three wires are preferably in an elongated configuration, substantially parallel to a longitudinal axis of the filter.

Preferably, the transverse dimensions of the first and second anchoring portions are substantially equal and the transverse dimensions of the first and second filtering portions are substantially equal, and each of the filtering portions progressively increases in diameter towards its respective anchoring portion.

The present invention also provides a surgical apparatus comprising a vessel filter having a first portion, a second portion and an intermediate portion between the first and second portions, wherein the first portion increases in diameter from the intermediate portion towards a first end, and the second portion increases in diameter from the intermediate portion towards a second end, and a region closer to the intermediate portion forms a filtering portion. The filter is formed by at least one wire, each wire forming a part of the first, second and intermediate portions. Preferably, a retaining sleeve is provided at the intermediate portion to retain the at least one wire. A tubular anchoring member preferably extends from the first and second portions and has opposing sharpened ends to engage the vessel wall.

The present invention also provides a method of implanting a vein filter in the inferior vena cava of a patient comprising the steps of:

inserting a catheter through a femoral vein or an internal jugular vein having a filter positioned therein in a collapsed configuration so that a first, second and third wire of the filter are in a substantially elongated configuration;

delivering cold saline into the catheter to maintain the filter in the collapsed configuration;

releasing the filter from the catheter to enable the filter to move to an expanded configuration in response to warming by exposure to body temperature, in the expanded configuration a pair of mounting portions expand to a first diameter and a pair of filtering portions expand to a second smaller diameter.

The method may further comprise the steps of opening a valve to enable infusion of cold saline into the catheter. Preferably, the step of releasing the filter comprises withdrawing the catheter to initially eject a first of the pair of mounting portions and a first of the pair of filter portions.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiment(s) of the present disclosure are described herein with reference to the drawings wherein:

Figure 1 is a perspective view of a first embodiment of the vein filter of the present invention shown in the expanded configuration;

Figure 2 is a side view of the vein filter of Figure 1;

Figure 3 is a top view of the vein filter of Figure 1;

Figure 4 is a front view of the vein filter of Figure 1;

Figure 5A is a perspective view of the vein filter of Figure 1 in the collapsed configuration for delivery through a catheter or sheath into the vessel;

Figure 5B is an enlarged view of a portion of the filter in the collapsed configuration of Figure 5A showing the intermediate and proximal crimping sleeves;

Figure 5C is an enlarged side view of the portion of the filter shown in Figure 5B;

Figure 6A is a transverse cross-sectional view of the vein filter of Figure 1 in the collapsed configuration of Figure 5 showing an anchor member and adjacent wire within the delivery sheath;

Figure 6B is a transverse cross-sectional view of the vein filter of Figure 1 in the collapsed configuration of Figure 5, showing a crimping sleeve encircling two wires within the delivery sheath;

Figure 7 is perspective view of a second embodiment of the vein filter of the present invention formed of a single wire and shown in the expanded configuration;

Figure 8 is a perspective view of a third embodiment of the vein filter of the present invention formed of a single wire with a central (intermediate) crimping sleeve, and shown in the expanded configuration;

Figure 9 is a perspective view of another alternate embodiment of the vein filter of the present invention having two filtering portions and two anchoring portions shown in the expanded configuration;

Figure 10A is side view of the vein filter of Figure 9 in the expanded configuration;

Figure 10B is a side view similar to Figure 10A except at a slightly different angle;

Figure 10C is a view similar to Figure 10A except showing an alternate embodiment of the filter of the present invention in the expanded configuration having multiple anchoring members on each of the wires;

Figure 11 is a front view of the vein filter of Figure 9 in the expanded configuration;

Figure 12A is a perspective view of the vein filter of Figure 9 in the collapsed configuration for delivery through a catheter or sheath into the vessel;

Figure 12B is an enlarged side view of the distal and middle portions of the vein filter of Figure 9 in the collapsed configuration of Figure 12A;

Figure 12C is an enlarged perspective view of a portion of the vein filter of Figure 12A showing the axial displacement of the anchoring members;

Figure 12D is a view similar to Figure 12A except showing the alternate embodiment of the vein filter of Figure 10C having a series of anchoring members on each of the wires at the proximal and distal portions;

Figure 12E is a side view of the middle and distal portions of the filter of Figure 12D;

Figure 13A is a transverse cross-sectional view of the vein filter of Figure 9 in the collapsed configuration of Figure 12 showing the crimping sleeve encircling three wires within the delivery sheath;

Figure 13B is a transverse cross-sectional view of the vein filter of Figure 9 in the collapsed configuration of Figure 12 showing an anchor member and adjacent wires within the delivery sheath;

Figures 14-17 illustrate the steps of insertion of the vein filter of Figure 9 within the inferior vena cava of a patient in accordance with a first method, wherein:

Figure 14 illustrates insertion of the delivery catheter through the femoral vein;

Figure 15 illustrates the delivery sheath being advanced to the inferior vena cava just below (upstream) the juncture of the renal arteries;

Figure 16 illustrates the delivery sheath being withdrawn to enable one of the anchoring portions and one of the filtering portions to move to the expanded configuration; and

Figure 17 illustrates the delivery sheath fully withdrawn to expose the other filtering portion and the other anchoring portion filter to enable movement to the expanded configuration;

Figure 18 is an enlarged view of the expanded filter of Figure 17 showing a blood clot captured in the filter;

Figure 19 is an enlarged view of one embodiment of the anchoring tube of the present invention having ground edges engaging the vessel wall;

Figure 20 is an enlarged view of an alternate embodiment of an anchoring tube of the present invention having beveled edges engaging the vessel wall;

Figures 21-23 illustrate insertion of the vein filter of Figure 9 within the inferior vena cava in accordance with a second method, wherein:

Figure 21 illustrates insertion of the delivery catheter through the right jugular vein;

Figure 22 illustrates the delivery sheath being advanced downwardly past the juncture of the renal arteries to the inferior vena cava; and

Figure 23 illustrates the delivery sheath being withdrawn to enable one of the anchoring portions and filtering portions to move to the expanded configuration; and

Figure 24 illustrates insertion of the vein filter of Figure 9 into the superior vena cava in accordance with a third method of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Turning now to the drawings, wherein like reference numerals identify similar or like components throughout the several views, several embodiments of vein filters of the present invention are described for placement within the inferior vena cava to capture blood clots or other particles which could otherwise pass to the lungs. These filters are movable from a low profile collapsed configuration to facilitate insertion through the delivery sheath to an expanded position to enable the anchoring members to atraumatically contact the vessel walls to secure (mount) the filter within the inferior vena cava. The wire(s) which form the vein filters of the present invention are looped to form an anchoring portion and a narrowed filtering portion, as will be described in detail below.

With reference first to the embodiment of Figures 1-6, and turning initially to Figure 1, this first embodiment of the vein filter of the present invention is designated generally by reference numeral 10. Vein filter 10 is formed by a pair of wires, designated by reference numerals 12 and 14. Wires 12 and 14 are preferably circular in cross-section having a diameter preferably ranging from about .011 inches to about .020 inches, and preferably about .012 inches. The wires 12 and 14 are held together, side by side, at their distal ends by a distal crimping sleeve 20 and held together, side by side, at their proximal ends by a proximal crimping sleeve 22. To provide additional support and overall rigidity to the filter 10, a central or intermediate crimping sleeve 24 is provided at an intermediate portion of wires 12 and 14 to retain middle portions of the wire together in a side-by-side relationship.

Although preferably held side by side by crimping sleeves, the wires can also be held by other means such as being welded or glued.

As can be appreciated from Figures 1-2, the wires 12 and 14 are wound in identical manners, except opposite to one another. That is, wire 12, starting from proximal crimping sleeve 22, weaves back and forth across an imaginary centerline "C" (or central longitudinal axis) to form a series of loops 12b, 12d, 12g, 12i and 12k, on one side of the centerline. Bends or curves 12a, 12c, 12e, 12f, 12h, 12j and 12l are on the other side of the centerline and form transitions for formation of the loops in wire 12. Each of the bends 12a, 12c, 12e, 12f, 12h, 12j and 12l faces in the downward direction enabling each of the loops 12b, 12d, 12g, 12i and 12k to open in an upward direction as oriented in Figures 1 and 2.

Wire 14 also weaves back and forth across the centerline forming loops 14b, 14d, 14g, 14i and 14k on one side of the centerline and curves and bends 14a, 14c, 14e, 14f, 14h, 14j and 14l on the other side of the centerline to form transitions for the loops. Each of the bends 14a, 14c, 14e, 14f, 14h, 14j and 14l faces in the upward direction and each of the loops 14b, 14d, 14g, 14i and 14k opens in the downward direction as oriented in Figures 1 and 2. Thus, viewed another way, wire 12 forms upwardly directed loops (as viewed in the orientation of Figures 1 and 2) and wire 14 forms downwardly directed loops with the wire loops and bends 12a-12l approximately 180 degrees out of phase with the corresponding wire loops and bends 14a-14l.

A central portion 12m, 14m of wires 12 and 14, respectively, forms partial loops and extends substantially linearly through the central crimping sleeve 24 where they are contiguous and aligned side by side. The wires 12 and 14 are preferably also contiguous as they extend linearly through the proximal, and distal crimping sleeves 22, 20, respectively. Partial loops 12n and 14n are formed in wires 12 and 14 before extending through distal crimping sleeve 20 and partial loops 12p, 14p extend from proximal crimping sleeve 22. In the other regions, the wires preferably do not touch as the loops are spaced apart and the loops of wire 12 do not cross over the loops of wire 14.

The center of the radii of the loops on one side as viewed in Figure 1, i.e. loops 14i, 12g, 14d, and 12b, are preferably substantially aligned such that an imaginary line drawn through such centers would be substantially parallel to the longitudinal axis of the filter 10. The center of the radii of the loops 14k, 12i, 12d and 14b on the other side of the filter 10 are also preferably substantially aligned such that an imaginary line drawn

through such centers would be substantially parallel to the longitudinal axis of the filter 10. The two imaginary lines lie in substantially the same transverse plane.

The wires 12, 14 of filter 10 form an anchoring or mounting portion 30 and a filtering portion 28. The anchoring portion 30 is formed at a proximal portion to engage the vessel wall for securement of the filter 10. The filtering portion 28 is formed at a distal portion and has a diameter less than the diameter D1 (Figure 3) of the anchoring portion 30. The diameter of the filtering portion is sufficiently small to capture blood clots and prevent its passage through the filter 10.

It should be appreciated that the terms proximal and distal are utilized for convenience for orientation purposes, since if the filter 10 is inserted into the inferior vena cava through the internal jugular vein instead of the femoral vein, the portion closer to the user, e.g. the "proximal portion", will instead be the filtering portion 28.

clay In the illustrated embodiment, the anchoring portion 30, which includes the region between the intermediate and proximal crimping sleeves 24, 22, is substantially uniform in diameter (D1) or height. The filter portion 20, which includes the region between the intermediate sleeve 24 and the distal crimping sleeve 20, progressively decreases in diameter towards the distal sleeve 20 from diameter D2 to diameter D3. Consequently diameter D2 of filter portion 32 is greater than diameter D3 of filter portion 20. This decrease in diameter helps to cause migration of the blood clots towards the center of the filter 10 to facilitate dissolution by the blood flow. Thus, the region between the drawn diameters D2 and D3 functions as the filtering portion. As noted below, it should be appreciated that the anchoring and filtering regions are not rigidly defined and the diameters D2 and D3 and the portions 30 and 28 are identified for convenience.

Preferably, the diameter D1 of the anchoring portion 30 ranges from about 18mm to about 30mm. The diameter D2 of the filtering portion 28 preferably ranges from about 17mm to about 29mm; and the smaller diameter D3 of the filtering portion 28 preferably decreases to as small as about .5mm at the distal sleeve 20. Other dimensions are contemplated.

It should be understood that the anchoring portion 30 defined herein defines a region of the filter which is utilized to retain (mount) the filter 10 inside the vessel and the filtering portion 28 defines the region which captures particles such as blood clots.

collapsed configuration is illustrated with cylindrical tubes 50, it is understood that anchoring tubes 40 would be positioned in a similar manner.

When collapsed, the first and second wires 12, 14 are in a straightened configuration substantially parallel with one another and substantially aligned with their respective longitudinal axis. The cylindrical anchoring members 50 are axially displaced to conserve space within the delivery catheter. Consequently, as shown in the transverse sections of Figures 6A and 6B, the largest cross sectional area occupied by the filter 10 is defined by the outer diameter D4 of one of the wires (e.g. wire 14) plus the outer diameter D5 of the anchoring tube 50. Since the other anchoring tube(s) are staggered, i.e. axially displaced, in the collapsed configuration, the overall collapsed diameter is minimized which would not be the case if the anchoring tubes 50 were axially aligned in the collapsed configuration since the diameter would then be defined by the sum of the diameters D5 of adjacent anchoring tubes. (2 x D5). This axial displacement of the anchoring tube thereby enables the size (diameter) of the delivery sheath 210 to be minimized. A slight gap, not shown, could be provided between the outer wall of the anchoring tube 50 and delivery sheath 210 to provide clearance to facilitate exit from the sheath 210.

Figure 6B shows the diameter of the two wires within the crimping sleeve 22, with the total cross sectional region occupied by the collapsed filter defined by the outer diameter D6 of the sleeve 22. A slight gap between the outer diameter of the crimping sleeve 22 and delivery sheath 210 is designated by reference letter "g".

Stated another way, the inner diameter of the crimping sleeve is equal to the sum of the outer diameters of the wires 12, 14, with the thickness "t" of the sleeve defined by the distance between the inner wall and outer wall and being sufficient to rigidly retain the wires. For this given diameter, the anchoring tube is preferably maintained equal to or less than the numerical difference between the outer diameter of the sleeve and the outer diameter of the wire. This keeps the overall cross-sectional region (or height) of the filter in the collapsed position at a minimum as other portions of the filter 10 in the collapsed position will not exceed the outer diameter of the crimping sleeve.

As noted above, the outer diameter D4 of the wires 12 and 14 is preferably about .012 inches. The inner diameter D6 of each crimping sleeve preferably ranges from

about .022 inches to about .040 inches, and preferably is about .024 inches. That is, the inner diameter of the crimping sleeve is preferably twice the diameter of the wire. The outer diameter of each crimping sleeve preferably ranges from about .050 inches (18 gauge) to about .065 inches (16 gauge), and is preferably about .058 inches (17 gauge). The outer diameter D5 of the anchoring tube preferably ranges from about .030 inches to about .054 inches, and is preferably about .046 inches. With these dimensions, a 6 French delivery sheath 27 (2 mm in outer diameter) to deliver the filter 10 can be utilized.

To enable movement between an expanded and collapsed configuration, wires 12 and 14 are preferably made of shape memory metal material, such as Nitinol, a nickel titanium alloy. The memorized configuration of the filter 10 is shown in Figure 1. To facilitate passage of the wires 12 and 14 through the lumen of the delivery sheath 210 and into the vessel, cold saline is injected into the delivery sheath 210 and around the wires 12 and 14 in their collapsed position within the delivery sheath 210. This shape memory material characteristically exhibits rigidity in the austenitic state and more flexibility in the martensitic state. The cold saline maintains the temperature dependent wires 12, 14 in a relatively softer condition as they are in the martensitic state within the sheath. This facilitates the exit of wires 12 and 14 from the sheath 210 as frictional contact between the wires 12, 14 and the inner surface of the sheath would otherwise occur if the wires were maintained in a rigid, i.e. austenitic, condition.

Once ejected from the delivery sheath 210, the wires are no longer cooled and are exposed to the warmer body temperature, which causes the wires to return their austenitic memorized configuration of Figure 1.

The filter 10 can be inserted through the jugular vein in the neck of the patient or through the femoral vein in the leg of the patient. It can also be inserted through the superior vena cava. If inserted through the femoral, the filter would be positioned within sheath 21 so that the anchoring portion 30 is closer to the user and the filtering portion 28 is further from the user. If inserted through the jugular or superior vena cava, the filter would be positioned within sheath 21 so that the anchoring portion 30 is further from the user and the filtering portion 28 is closer to the user. Insertion of the filter will be better understood from the detailed description below of the filter insertion methods.

Figure 8 illustrates an alternate embodiment of the filter of the present invention, designated generally by reference numeral 60. Filter 60 is similar to filter 10, except instead of being formed of two wires, filter 60 is formed of a single wire 61. Filter 60 is crimped at the proximal end by sleeve 72 and at a middle or intermediate portion by crimping sleeve 74. The distal end 66 of filter wire 60 loops around at loop 68, and is therefore not crimped with a sleeve as in the embodiment of Figure 1. Filter 60 also preferably has anchoring tubes (not shown) on anchoring portion 62 similar to anchoring tubes 40 of Figure 1 or tube 50 of Figure 5 on loops 67 and 69. In all other respects, e.g. narrowed filtering portion 64, loops about 180 degrees out of phase, etc., filter 60 is identical to filter 10.

Figure 7 illustrates another alternate embodiment of the filter of the present invention formed by a single wire. Wire 82 of filter 80 wraps in a similar fashion as wire 61 of filter 60. That is, wire 82 forms alternating loops, i.e. downwardly directed and upwardly directed, as oriented in Figure 7, as it extends from a proximal end 85 in anchoring portion 86 to distal loop 87 at a filtering portion 88. Wire 82 then extends proximally from the distal loop 87 in an alternating loop pattern forming upwardly and downwardly directed loops. Filter 80 preferably includes a proximal crimping sleeve (removed to illustrate the wire) to retain the free ends 87, 89 of wire 82. Filter 80 also preferably includes an anchoring tube (not shown) on respective loops of the anchoring portion 86, similar to anchor 40 of Figure 1 or anchor 50 of Figure 5.

In the embodiments of Figures 7 and 8, the wire loops at the distal end and the wire ends are crimped, welded or secured by other means at the proximal end. It is also contemplated that alternatively the wire can loop at its proximal end and the two ends secured at the distal end.

An alternate embodiment of the filter of the present invention, having two anchoring portions and two filtering portions is illustrated in Figures 9 –13 and designated generally by reference numeral 100. The filter 100, having two symmetric anchoring and filtering portions, can be inserted into the inferior vena cava in either direction, e.g. downwardly from the right jugular vein access or upwardly from the femoral vein access, without concern of its proximal/distal orientation.

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With initial reference to Figures 9 and 10, filter 100 is formed by three wires 112, 114 and 116. The three wires 112, 114 and 116¹¹⁰ form first and second anchoring portions 102, 104 and first and second filtering portions 106, 108. The first filtering and anchoring portions 102, 106 extend between proximal crimping sleeve 120 and intermediate (central) crimping sleeve 124; the second filtering portion 108 and anchoring portion 104 extend between intermediate crimping sleeve 124 and distal crimping sleeve 122. Anchoring portion 102 is substantially identical to anchoring portion 104, except it extends in the opposite direction. Similarly, the filtering portion 106 is substantially identical to filtering portion 108 except it also extends in the opposite direction. By providing two symmetrical portions, the filter can be placed inside a delivery catheter and inserted either through the jugular vein or the femoral vein using the same delivery catheter and in either proximal/distal orientation.

As mentioned above with respect to the first embodiment, although the wires are described as being held in side by side relationship by a crimping sleeve, alternatively the wires can be welded, glued, or held together by other means.

The provision of two anchoring portions 104, 102 on opposing ends helps to center the filter 100 within the vessel which in turn helps to maintain the captured blood clots in the center of the filter 100. If the blood clots are maintained in the center, they will more easily be dissolved or washed away by the blood flow.

The three wires 110, 112, 114 each form a series of loops which are about 120 degrees out of phase with the loops of the adjacent wires. More specifically, wire 110 forms three loops 110a, 110b, and 110c between the proximal and intermediate crimping sleeves 120, 124 with loops 110a and 110c extending in a first direction and a loop 110b extending in an opposite second direction. Wire 110 further forms two loops 110d and 110f, extending in the second direction and one loop 110e extending in the first direction in the region between the intermediate crimping sleeve 124 and the distal crimping sleeve 122.

Wire 112 in the first anchoring/filtering portion defined between the proximal and intermediate crimping sleeves 120, 124 forms two loops 112a, 112c extending in a third direction and a third loop 112b extending in a fourth direction opposite the third direction. In the second anchoring/filtering portion defined between the intermediate and

distal crimping sleeves 124, 122, loops 112d and 112f of wire 112 extend in the fourth direction and loop 112e extends in the third direction.

Wire 114 in the first anchoring/filtering portion defined between the proximal and intermediate crimping sleeves, forms two loops 114a, 114c extending in a fifth direction and a third loop 114b extending in a sixth opposite direction. Loops 114d and 114f extend in the sixth direction and loop 114e extends in the fifth direction. These loops 114d, 114e and 114f are formed in the second anchoring/filtering portion between the distal and intermediate crimping sleeves 122, 120.

The corresponding loops of wires 110, 112, 114, e.g. loops 110a, 112a, 114a; loops 110b, 112b, 114b; etc., are preferably about 120° out of phase. It should be appreciated that arrangements other than 120 degree spacing are contemplated. Additionally, "opposite" directions of the loops is not limited to 180 degrees, but encompasses different directions.

An anchoring member 140 is positioned on each of the wires 110, 112, 114 in the first anchoring portion 102 and the second anchoring portion 104. More specifically, the anchoring members 140 are positioned on the region of the wires 110, 112 and 114 having the largest diameter (height) H or greatest distance from the longitudinal axis, namely on loops 110a, 112a, 114a and loops 110f, 112f and 114f as shown. The distances H are preferably substantially equal but alternatively can vary. Note the anchoring members are removed from Figures 9, 10B and 11 for clarity.

With reference to Figure 10A, the anchoring (securement) member has a lumen 142 to receive the respective wire therethrough. The anchoring member 140 is preferably a cylindrical shaped metallic tube with opposed sharpened edges 144 formed by grinding the ends. It should be understood, that the anchoring tube 40 of Figure 1 with sharpened bevelled edges could alternatively be utilized. The ground edges 144 are designed to frictionally engage the vessel wall in the manner described in more detail below to retain the filter 100 inside the vessel.

In the alternate embodiment of Figure 10C, filter 100' has a pair of anchoring members 140' on each of the wires 110', 112' 114' in the first anchoring portion 102' and in the second anchoring portion 104'. In all other respects, the filter 100' is identical

to filter 100 with corresponding parts labeled with a prime ('). It is also contemplated that additional anchoring members can be placed on the wires 110', 112' and 114'.

The diameter or height of the anchoring portions 102, 104 is greater than the diameter of the filtering portions 106, 108. That is, the diameter of the filter 100 increases from the intermediate region (or from intermediate crimping sleeve 124) towards the proximal end and towards the distal end, thereby forming two reduced diameter filter portions closer to the intermediate region of the filter 100. Viewed another way, two symmetrical portions are provided, each having a filtering portion decreasing in diameter toward the intermediate portion. Since the filtering portions progressively decrease towards the center, the captured blood clots will be directed toward the center of the filter 100 and the center of the blood vessel, thereby enabling it to be more easily dissolved or washed away by the blood flow.

Diameters E1 and E2 in Figure 10B are taken in one transverse line of the anchoring portion 102 and filtering portion, respectively, for an example of how these diameters change. It should be appreciated, that within each portion, the diameters could vary. In a preferred embodiment the diameter of the first and second anchoring portions 102, 104 ranges from about 18mm to about 30mm, and the diameter of the first and second filtering portions preferably progressively decreases to about .5mm. Other dimensions are also contemplated.

The compactness of the filter 100 of the present invention can be appreciated by reference to Figures 12-13. In the collapsed configuration, the wires 110, 112, and 114 are substantially straight and substantially parallel, i.e. substantially aligned with a longitudinal axis. Adjacent anchoring tubes 140 are axially displaced to minimize the overall diameter of the filter 100. Consequently, the largest diameter of the filter 100 in the collapsed configuration for delivery will be defined by the outer diameter F1 of one of the crimping sleeves, e.g. crimping sleeve 124 of Figure 12A. The transverse cross sectional view of Figure 13B shows the dimensional relationship of the anchoring member 140 and wires, with each wire having, by way of example, a diameter of about .011 inches to about .020 inches, and preferably about .012 inches. The crimping sleeve, which circumscribes the three circular cross-sectional wires, is defined by a diameter factor of 2.155, meaning that the inner diameter of the sleeve can be as small as the 2.155

times the wire diameter. Therefore, if the wire diameter is about .012 inches, the inner diameter of the crimping sleeve can be about .0256 inches ($2.155 \times .012$). If the wall thickness of the sleeve is about .010 inches, the outer diameter would be about .0456 inches. These dimensions are provided by way of example. The outer diameter of the anchoring tube is preferably selected so that in the collapsed configuration of the filter, the anchoring tube and adjacent wires do not occupy a transverse dimension exceeding the outer diameter of the crimping sleeve, such as shown in Figure 13B, to maintain the low profile of the filter in the collapsed configuration. Conversely, if the diameter of the anchoring tube is the reference dimension, then the crimping sleeve outer diameter preferably does not exceed the diameter of the anchoring tube and the adjacent wires to maintain the low profile.

Figures 12D and 12E illustrate the collapsed configuration of filter 100' of Figure 10C with a pair of anchoring members 140' on each of the three wires at the distal portion adjacent distal crimping sleeve 122' and at the proximal portion adjacent proximal crimping sleeve 120'.

Like filter 10, filter 100 is preferably made of shape memory metal, e.g. Nitinol. Cold saline is injected into the delivery catheter and around the wires 110, 112, 114 in their collapsed position within the delivery catheter to facilitate passage of the wires through the lumen of the catheter and into the vessel. This shape memory material characteristically exhibits rigidity in the austenitic state and more flexibility in the martensitic state. The cold saline maintains the temperature dependent wires 110, 112, 114 in a relatively softer condition as they are in the martensitic state within the catheter. This facilitates the exit of the wires from the catheter as frictional contact between the wires and the catheter inner surface would otherwise occur if the wires were maintained in a rigid, i.e. austenitic, condition. Once ejected, the filter 100 is warmed by body temperature, causing its transition to its austenitic memorized configuration of Fig. 10A.

Turning now to the methods of insertion of the filter 100, the filter 100 can be inserted through the femoral vein or the right jugular vein and into position in the inferior vena cava, just below the renal arteries. Since the filter 100 is symmetrical, e.g. two filtering portions, it can be loaded into the delivery sheath or catheter in either orientation and inserted in either direction into the vena cava.

One method of insertion of the filter 100 of the present invention is illustrated in Figures 14-18. A delivery catheter 200 having a hub 202 is inserted through a leg incision and into the femoral vein "F" of the patient. The delivery catheter 200 is advanced through the iliac arteries into the inferior vena cava just below (upstream) of the renal arteries. Note that the delivery catheter is introduced through an introducer sheath which is not shown for clarity. The introducer sheath is inserted over a guidewire (also not shown) and advanced to the target site. The guidewire is then removed and the delivery catheter is inserted through the lumen in the sheath to the target vessel.

Extending from hub 202 of delivery catheter 200 is tubing 204 and valve assembly 206 to enable saline to be injected into delivery catheter 200 to maintain the softened martensitic state of the vein filter within the catheter 200 so the vein filter is in the substantially straightened configuration as in Figure 12. A one-way stopcock can be provided to control saline infusion. A metal retaining rod 205 is positioned within the delivery catheter 200 and inserted with the catheter 200.

Once the distal tip 207 of catheter 200 is advanced to the site, i.e. in the inferior vena cava below the renal arteries, the delivery catheter 200 is withdrawn proximally, with rod 205 held in a fixed position to ensure the filter 100 is not pulled back with the catheter 200. Withdrawal of the catheter 200 exposes one of the anchoring portions, e.g. second anchoring portion 104 and one of the filtering portions, e.g. second filtering portion 108, enabling return to the austenitic expanded configuration as the filter is warmed by body temperature (see Figure 16). Further withdrawal of the delivery catheter 200, releases the other filtering and anchoring portions, e.g. first filter portion 102 and first anchoring portion 106, as shown in Figure 17. In this position, anchoring tubes 140 engage the vessel wall to retain the filter 100 inside the vessel. The filtering portion 106 will catch blood clots or other small particles to prevent passage to the heart or lungs. Figure 18 illustrates a blood clot "P" captured in the filtering portion 106 of the filter 100. Note that if the filter 100 was loaded in catheter 200 in the opposite direction, the filtering portion 104 would be upstream of filtering portion 102, when placed within the vessel, and the filtering portion 104 would function to capture blood clots.

Figures 19 and 20 illustrate the engagement of the anchoring tube with the vessel. In Figure 19, the surface 145 of tube 140 presses inwardly into the vessel wall, creating

an indented region so that ground edges 142 of anchoring tube 140 can press against opposing vessel wall portions "v1" and "v2". This frictional contact retains the filter 100.

In the embodiment of Figure 20, the engagement of the anchoring tube 40 of Figure 1 is illustrated. Bevelled edges 44, 46 engage opposing sides "v1" and "v2" of the vessel, formed by the indentation as surface 45 presses against the vessel wall.

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In the alternate embodiment of Figure 25, a series of anchoring tubes 140 on the distal portion and proximal portion of each wire engage the vessel wall.

Figures 21-23 illustrate an alternate insertion method through the right internal jugular vein "j". Delivery catheter 200 having a hub 202, a tube 204 and valve assembly 206 for injection of saline is inserted through the right jugular vein, and advanced past the heart and into the inferior vena cava just past the juncture of the renal arteries. The filter 100 is contained within the delivery catheter 200 in the collapsed configuration. The delivery catheter 200 is advanced adjacent the surgical site so that distal tip 20 extends past the juncture of the renal arteries as shown in Figure 22. The delivery catheter 200 is then retracted, with rod 205 preventing proximal movement of the filter 100, exposing the second filtering portion and second anchoring portion 102 (Figure 23), allowing it to expand from its straightened configuration to its austenitic expanded configuration as it is warmed by body temperature. Further withdrawal of the delivery catheter 200 in the direction of the arrow will release the first anchoring portion 104 and the first filtering portion 108, allowing expansion against the wall of the vessel, to the position of Figure 18. Blood clots could then be captured in filtering portion 106.

As can be appreciated, the filter 100 can be inserted into the inferior vena cava in either orientation since once expanded, the upstream filtering portion will capture blood clots and the two anchoring portions will help retain the filter 100 anchored and centered in the vessel.

Figure 24 illustrates another alternate method of insertion wherein the delivery catheter 200 is inserted directly into the superior vena cava "s" and advanced into the inferior vena cava in the same manner as described in Figures 22 and 23.

The other embodiments of the filters, i.e. filters 10, 60, and 80, can be inserted through the femoral vein, jugular vein, superior vena cava, etc. in a similar manner as described above for filter 100.

In the foregoing embodiments, preferably, the filter is released by withdrawal of the delivery catheter as described. However, alternatively, the filter can be released by pushing or advancing the filter from the delivery catheter. Additionally, release can be achieved by a combination of withdrawal of the catheter and advancement of the filter.

It should also be appreciated that the terms proximal and distal for filter 100 (and filter 100') are utilized for convenience for orientation purposes, since the filter can be inserted in either direction.

While the above description contains many specifics, those specifics should not be construed as limitations on the scope of the disclosure, but merely as exemplifications of preferred embodiments thereof. For example the dimensions of the components have been provided by way of example and other dimensions are contemplated. Also, although filter embodiments utilizing one, two or three wires are described, additional wires can be utilized to form the filter or fewer than the two or three wires can be used to form the respective filter. Additionally, the filter can be inserted in other regions of the body besides the inferior vena cava. Those skilled in the art will envision many other possible variations that are within the scope and spirit of the disclosure as defined by the claims appended hereto.